EFFECT OF INCREMENTAL PATTERN TRANSFORMATION STRATEGY ON ACADEMIC ACHIEVEMENT, JOB TASK PERFORMANCE AND LEARNING SATISFACTION AMONG VOCATIONAL TRAINEES

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For those who I love most

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ABSTRACT

Acquisition of conceptual and procedural knowledge is often challenging especially when the content deals with symbolic representations whereas not limited to memorizing the symbol but also requires a learner to have multiple factual knowledge associated with the real representation. The aim of this study was to test the effect of using incremental pattern transformation materials (*i*OST) – theoretically grounded materials - on conceptual and procedural knowledge acquisition among vocational trainees. The *i*OST was designed to enhance trainees' learning of symbolic representations in electrical circuit diagrams. The quasi-experimental design method was used with 110 vocational trainees who were taking the vehicle air conditioning course from two vocational training centres. Trainees were divided into three groups, two treatment groups (assigned to paper-based *i*OST and animation-based *i*OST) and one control group. The duration of study was six weeks. Pre-test and post-test were used for assessing academic achievement, while practical test and a questionnaire were used for job task performance and learning satisfaction respectively. The ANCOVA, Chi-Square Test and Mann-Whitney U Test were used to test for differences between groups on academic achievement, job task performance and learning satisfaction respectively while the Spearman's rank-order correlation method was used to assess associations between learning satisfaction, conceptual and procedural knowledge. The results show that the experimental groups are better on academic achievement (effect size = .329) and job task performance (effect size = .657) with both groups exhibiting high learning satisfaction. The findings indicate that the *i*OST materials (irrespective of media) are effective in promoting learning of symbolic representation and support the acquisition of conceptual and procedural knowledge for better task performance. The findings also suggest that, appropriately designed learning materials can support learning and job performance.

ABSTRAK

Penguasaan pengetahuan konseptual dan prosidural sering mencabar terutamanya apabila isi kandungannya berkaitan dengan perwakilan simbol yang mana tidak terhad kepada mengingati simbol sahaja tetapi juga pelajar perlu memiliki banyak fakta yang dikaitkan dengan perwakilan sebenar. Kajian ini bertujuan untuk menguji kesan penggunaan bahan transformasi corak berjujukan (*i*OST) - bahan berasaskan teori - terhadap penguasaan pengetahuan konseptual dan prosedural dalam kalangan pelatih vokasional. *i*OST direka untuk meningkatkan pembelajaran para pelajar terhadap perwakilan simbol dalam gambar litar elektrik. Kaedah kuasi eksperimen digunakan melibatkan 110 orang pelatih vokasional yang mengambil kursus penyaman udara kenderaan dari dua buah pusat latihan vokasional. Pelatih dibahagikan kepada tiga kumpulan, dua kumpulan rawatan (diberikan bahan *i*OST berasaskan kertas dan *i*OST berasaskan animasi) dan satu kumpulan kawalan. Tempoh pengajian adalah selama enam minggu. Ujian pra-ujian dan ujian pasca digunakan untuk menilai pencapaian akademik, manakala ujian praktikal dan soal selidik digunakan untuk menilai prestasi kerja dan kepuasan belajar masing-masing. Ujian ANCOVA, Chi-Square dan Mann-Whitney U digunakan untuk menguji perbezaan antara kumpulan dalam pencapaian akademik, prestasi kerja dan kepuasan pembelajaran masing-masing manakala korelasi urutan peringkat Spearman digunakan untuk melihat kesatuan antara kepuasan pembelajaran, pengetahuan konseptual dan prosidural. Hasil dapatan menunjukkan keputusan kumpulan eksperimen lebih baik pada pencapaian akademik (saiz kesan = .329) dan prestasi kerja (saiz kesan = .657) dengan kedua-dua kumpulan menunjukkan kepuasan belajar yang tinggi. Penemuan menunjukkan bahawa bahan-bahan *i*OST (tanpa mengira media) adalah berkesan dalam mempromosikan pembelajaran perwakilan simbol dan menyokong penguasaan pengetahuan konseptual dan prosidural untuk prestasi tugas yang lebih baik. Penemuan ini juga mencadangkan, bahan pembelajaran yang direka dengan baik dapat menyokong pembelajaran dan prestasi kerja.

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LIST OF SYMBOLS AND ABBREVIATIONS

ICT	-	Information and Communication Technology
TVET	-	Technical and Vocational Education and Training
*i*OST	-	*incremental* Object to Symbol Transformation
MARA	-	Majlis Amanah Rakyat
IKM	-	Institut Kemahiran Mara
KKTM	-	Kolej Kemahiran Tinggi Mara
UNESCO	-	United Nation for Education, Science and Cultural Organization

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Chapter 1

INTRODUCTION

1.1 Overview

Development of occupational skills is the goal of Technical and Vocational Education and Training (TVET) as indicated by its definition as "…term referring to those aspects of the educational process involving, in addition to general education, the study of technologies and related sciences, and the acquisition of practical skills, attitudes, understanding and knowledge relating to occupations in various sectors of economic and social life." (Varis, 2011) (p. 2). TVET emphasizes the "learning by doing" approach which enhances the development individual's skills for real jobs (Langthaler, 2013). Furthermore, TVET courses are based on the concept of competency (Karmel, 2011) as needed in an occupational task. In short, all TVET programmes are aimed at producing workers who are competent in job tasks.

To acquire occupational competence, TVET trainees must have the necessary occupational domain-specific skills namely cognitive skills, motor skill (job skills), and affective skills (Kraiger, Ford, & Salas, 1993). Cognitive skills are needed to acquire occupational domain-specific factual information, comprehend the content, and apply the knowledge in job tasks (Lachman, Lachman, & Butterfield, 2015). Job skills, on the other hand, are needed by a worker to ensure that job specific operations and process will run smoothly (Kraiger et al., 1993). Both cognitive and job skills will not produce optimum worker performance when attitudes towards job task (affective skill) are not taken care off. Attitude influences a person's efforts in acquiring knowledge and understanding related to one's job (Yasak & Alias, 2015). Attitudes also influences a person's motivation to accomplish good job quality. Theoretically, to become a good employee, an individual need to know about things related to the job, how to do the work in working environment, and have a good attitude toward the job. Thus, teaching and learning in TVET must cater to these needs to produce the desired competence in future workers.

Traditionally, job skills or motor skills have been the emphasis in TVET (Pang, 2011). However, with the emergence of the Industrial Revolution 4.0 (IR 4.0) having motor skills alone is not sufficient to produce competent workers. Having cognitive skills are gaining greater importance in IR 4.0 era. This is due to the fact that job tasks in IR 4.0 demand greater knowledge integration as IR 4.0 involves automation production line which is based on the use of cyber-physical system (Hartmann & Bovenschulte, 2013), the internet of things and artificial intelligence. Furthermore, future workers need to equip themselves with Industrial Revolution 4.0 skills, such as collaboration and process awareness skill (Lucas, Spencer, & Claxton, 2012), which are soft skills (Geremew, 2018). To develop the necessary soft skills requires TVET trainees who are future workers to have adequate cognitive skills first.

To have adequate cognitive skills means that a person has the necessary conceptual and procedural knowledge to apply to their job tasks (Hodge, Atkins, & Simons, 2016; Harmen Schaap, Baartman, & de Bruijn, 2011). One of the features of conceptual knowledge is its rich connection to other knowledge (Rittle-Johnson & Schneider, 2012) including procedural knowledge. Both, conceptual and procedural knowledge, are integrated to create competency in applying the knowledge. In the TVET system, conceptual knowledge, procedural knowledge, and competency are the types of knowledge that are presented in the domain of application management (Paraskakis, Konstantinidis, & Tsantekidis, 2010). Although training on job tasks can develop hands-on experience of a person, he or she must be proficient in cognitive skill first before such training can be effective. Appropriate teaching and learning methods which are different from teaching method for motor skills (which has been the emphasis in the past) development are necessary. Thus, new approaches must be identified that can help TVET trainees develop appropriate conceptual and procedural knowledge which is classified as intellectual skill under Gagne's learning outcome.

1.2 Background of study

In helping TVET trainee to develop appropriate conceptual and procedural knowledge, everyone who is involved in teaching and training session, including instructors, departments staff, and institutions members must seriously consider the constructive alignment between content and the delivery methods (Biggs, 2014). Content must be analyzed to identify its specific characteristic. Typical characteristics of TVET content particularly in the engineering and technology discipline is the prevalent use of symbolic representation which are necessary to convey the information within (Barley, 1992).

Symbolic representation has been widely adopted to enhance the efficiency of technical communication. An example of symbolic representation is the use of schematic drawing and technical drawing which are used in multiple disciplines including engineering (Hong, 2014; Taşlıdere, 2013), architecture (McLaren, 2007) as well as fashion and design (Sahin, 2010). Thus, being able to translate symbolic representation is crucial in technical-oriented discipline such as TVET.

In addition to ensuring effective communication on technical matters, being able to read and understand symbols is also necessary to develop conceptual understanding (Taber, 2009) which underlies job performance including job task that demand understanding of circuit diagrams. Understanding of a circuit diagram is essential to all engineers, technicians and technical assistants as it is a form of communication between personnel-personnel and personnel-machine interaction (Kim et al., 2010). Electrical circuit diagram is a collection of abstract standard symbols that represent the electrical components (Johnson, Butcher, Ozogul, & Reisslein, 2014). Circuit diagram is part of the technical manual that is used across borders because the symbols and lines are standardized in electrical work. Circuit diagram used in technical electrical manual shows the flow of electric current (Peppler & Glosson, 2012), the voltage of electrical circuit (Johsua, 1984; Timmermann & Kautz, 2015) and the related electrical components involved in a circuit (Ozogul, Johnson, Moreno, & Reisslein, 2012). The availability of a circuit diagram can make error detection process in electrical components easier. Furthermore, the troubleshooting process can be easily understood with the use of a circuit diagram (Yasak & Alias, 2017). Thus, understanding symbolic representation in circuit diagram is crucial in electrical related job performance.

The inability to understand symbols in circuit diagram will reduce job competency and hinder good performance in occupation (Kim et al., 2010). For example, a person who cannot translate symbols for electrical components will not be able to read and understand circuit diagram which contain multiple interconnected electrical symbols. One such component is a resistor which "resistor" is the label,  is the symbol while  is the picture of the actual resistor. Symbolic representation holds four bits of information, which contains label (name), real component (actual physical material), symbol and function or operation of the component (Mautjana, 2015). Label or name of the component must be known in verbal and written form. Learners are usually exposed to the relationship between label and symbol and between actual component and label that represents the components. However, the relationship between symbol and actual component are not exposed in classroom session (Refer Figure 1.1). While, the function of the resistor is another information that students need to grasp. In domain of learning by Gagné (1971), the function and operation of component is classified into defined concept (Refer 1.2).

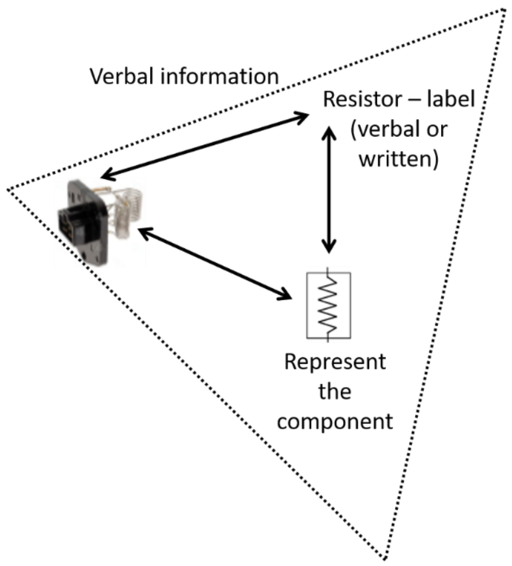

Figure 1.1: Relationship between an actual component with label and symbol.

Having conceptual knowledge means that a learner can make a meaningful connection between actual electrical components, label of the component and function of the component. Thus, having the ability to read symbolic representation of electrical component is an essential skill to conceptualize knowledge of electrical circuit diagram. Having procedural knowledge means a person has knowledge of the sequence of how a task is to be accomplished. However, within a sequence, a person needs to have conceptual knowledge. In order to operate the sequence of task, a person needs to understand the conceptual knowledge first. Therefore, there is a relationship between conceptual knowledge and procedural knowledge. Thus, reading and understanding circuit diagram become a challenge to student due to the rich information that must be understood within it.

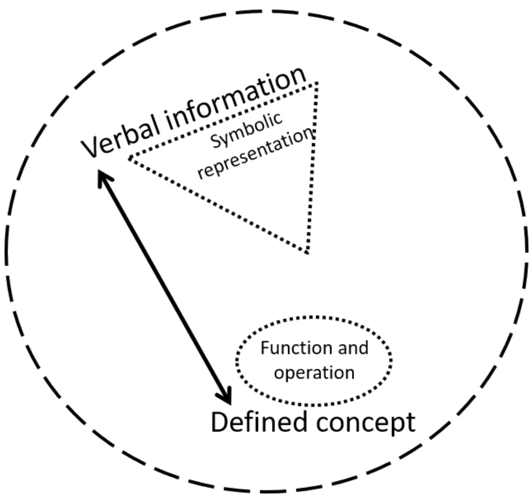

Figure 1.2: Relationship between verbal information and defined concept in symbolic content

The challenge in understanding a circuit diagram arises from the multitude of symbols used in representing a circuit. A circuit diagram often contains more than three symbols. For example, a simple circuit diagram, as shown in Figure 1.3, which contains 15 symbols may create cognitive overload among leaners. This is due to the many “bits” of information (related to concepts of electrical component) contained within the circuit that needs to be understood by a learner. Furthermore, a circuit diagram also contains many symbols representing different functions (in addition to component) (Konidaris, Kaelbling, & Lozano-Perez, 2018) causing multiple interpretations by students and often confusing to them (Taber, 2009). The vast amount of information can cause a problem especially among technical and vocational students. Students may experience high cognitive load on working memory when they need to recognise a symbol as the representation of an actual component and function (Sweller, 2005), misconceptions towards circuit diagrams (Brna, 1988) and failure to develop meaningful understanding of circuit diagram. Low ability students may experience greater challenges as teachers often assume that all students irrespective of ability has already mastered symbolic representation, leading teachers to leave out essential basic information on electrical circuit from teachers’ explanation (Barbara Tversky, 2004).

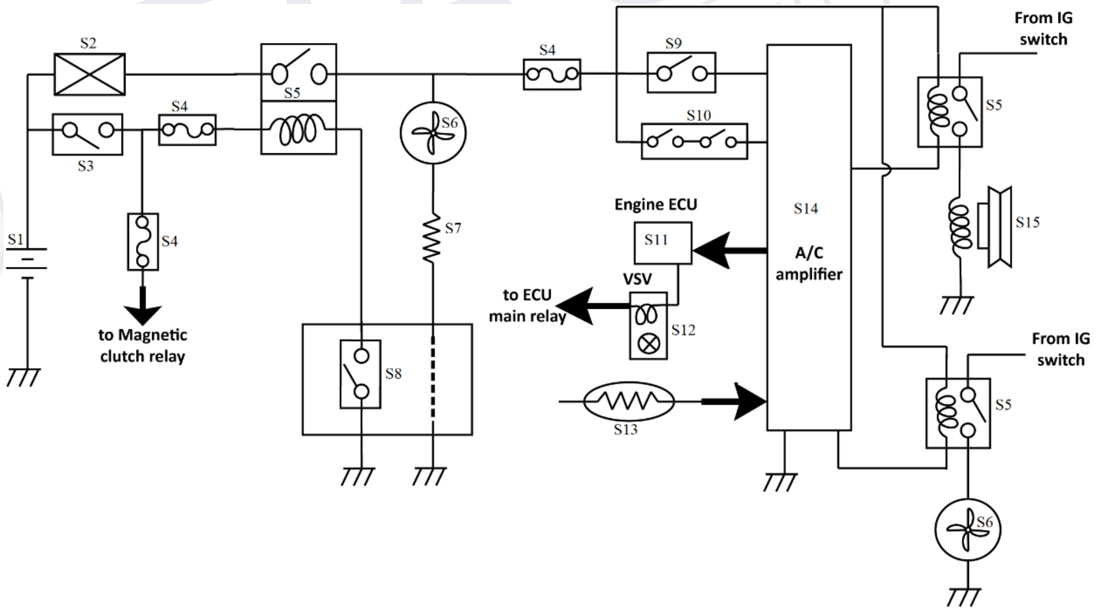

Figure 1.3: A simple electrical circuit diagram

Learning to read circuit diagram is especially challenging to students who are with lower academic ability such as those enrolled in skills and vocational training institutions (Alavi, Sail, & Awang, 2013). These are students who will later graduate to become technician and technical assistant. Having adequate conceptual and procedural skill which are categorised as intellectual skill learning outcome by Gagne is also essential for development of cognitive strategies learning outcome. Cognitive strategy is the foundation of problem solving skill (Gagné, 1971). Thus, there is a greater need to identify suitable teaching and learning method for those who are in the vocational institutions due to academic ability factor as suggested by Han & Song (2014).

Reading and translating circuit diagram skill among technical students is prerequisite to electricity-related field work. These skills are crucial among engineers, technicians, technical assistants and any technical workers (Burvill, Field, Abdullah, & Alias, 2016). However, some teachers find it challenging to develop students' conceptual understanding related to electrical concepts and often to repeat their explanation multiple times to make the symbols meaningful to students (Kambouri, 2016). This situation cause a misconception in interpreting circuit diagram (Twissell, 2014). Misconception happens due to unfamiliar symbols (Johnson et al., 2014), electrical load carried by each electrical component (Johsua, 1984) and function of each component in the interconnection of electrical components (Csanyi, 2016). Circuit diagram contains many symbols that look unusual and unfamiliar, especially to novice or non-technical learners. Each of unfamiliar symbols has a name and actual electrical component. Brain ability sometimes cannot make a proper connection between the actual component and the symbol that represents it (Reilly, Peelle, Garcia, & Crutch, 2016). Symbolic representation is used to translate information into a mental representation (Mayer, 2002). Misconception becomes worse when learners need to differentiate the function of each component. Learning circuit diagram needs students to master in recognizing the label (name of symbol), symbol, actual components and its function (van der Meij, 2007). The positive and negative electrical flow are also another contents in circuit diagram that they need to be proficient in (Peppler & Glosson, 2012; Taşlıdere, 2013).

Misconception in learning electrical circuit can give an impact to procedural knowledge (Burvill, Field, Abdullah, & Alias, 2016; Dym, 1993; Moreno, Reisslein, & Ozogul, 2009), job task performance (Han & Song, 2014) and learning satisfaction (Martín-Gutiérrez, Fabiani, Benesova, Meneses, & Mora, 2015; Sung & Mayer, 2012). Conceptual and procedural knowledge is important in learning electrical system (Jaakkola & Nurmi, 2004) because the electrical system is related to many safety cases. Students need to master both conceptual and procedural knowledge to make them appreciate why a procedure needs to be executed according to a particular standard (Hodge et al., 2016). Furthermore, students also need to acquire conceptual and procedural knowledge to be good in problem-solving (Burvill et al., 2016) which is also a challenge to TVET students. Thus, mastering conceptual and procedural knowledge is essential to occupational competence.

Lack of conceptual and procedural understanding in circuit diagram and electrical components will lead to incompetent in doing occupational task (Schneider & Stern, 2010) that requires reading circuit diagram. The incompetence is rooted in their ineffective skill of reading and translating circuit diagram which is the basic skill in understanding a circuit diagram (Yasak & Alias, 2015). During training, misconceptions of electrical symbols may lead to poor job task performance (Han & Song, 2014) as a consequence of wrong translation of symbols. The wrong translation of symbols will incur longer training duration due to the need for repetitions of training tasks (Shipstone, 1988), higher training cost due to the wasting of training resources (Ferris & Aziz, 2005) and decreasing student's motivation (Nye, Su, Rounds, & Drasgow, 2012). Further lost could be incurred due to learners dropping out from the training system which will affect human resource development goals.

Additionally, the lack of conceptual and procedural knowledge in circuit diagram also contribute to low satisfaction in learning. Satisfaction in learning is one of the attitudinal aspects to motivate students to continue the learning journey (So & Brush, 2008). Motivation, especially in learning, is cognitively-generated (Bandura, 2010). A person actively motivates their self to react to the receiving of new information. Most TVET students come from low academic background who often have low motivation in learning (Griffin, 2014). It is worsened when they are not satisfied in learning due to either the content or environment. Low satisfaction in learning contributes to the low congruence between personality and work environment (Perkmen & Sahin, 2013) that can create other issues related to individual emotion. Hence, low learning satisfaction may cause lack of conceptual and procedural understanding and may contribute to the poor task performance.

Teaching for the understanding of symbolic representations demands extra efforts from teachers and instructors as students find it hard to translate symbols into meaningful information (Isaacson, Srinivasan, & Lloyd, 2008) without proper guidance from the teacher. Learning to translate multiple symbolic representations makes high cognitive demand on the individual learner, as most symbols did not look like the real material or objects (Isaacson & Lloyd, 2008; Isaacson et al., 2008). Thus, learning to translate and interpret technical drawing, machinery drawing and process, electrical circuit diagram, and architectural drawing would demand high cognitive load which is restricted by an individual's cognitive limit especially for novices (Petre, 1995). Therefore, the symbolic representation may optimize the cognitive load (Lee, Plass, & Homer, 2006). Facilities in ICT can, however, be harvested to facilitate understanding of symbolic representations (Isaacson & Lloyd, 2013). Hence, learning symbolic representation such as circuit diagram requires designing new learning instruction (Twissell, 2014).

Initial observation on teaching and learning at the selected vocational institute indicates that circuit diagram has been taught using whiteboard and pen, question and answer, and also printed module/text reference. Learning symbolic representation in circuit diagram is not emphasised because all students come from standard academic background where they learned Science subject during upper elementary school. In Science subject, they have been introduced to electrical circuit, electrical current, and voltage (Kementerian Pendidikan Malaysia, 2001). Symbolic representation in circuit diagram has been previously taught and considered as already being mastered by the students. According to Taber (2009), learning symbolic conventions is similar to learning foreign language with new grammar and new vocabulary. Learning new language needs learners to do association between their first language and the new one. This method related to association learning theory which learners are trying to associate the symbol with the given name. However, based on the informal interview with the instructor at the selected institution (refer Appendix A), the subtopic of electrical and electronic wiring system diagram was the most challenging for students. Informal document analysis shows that TVET trainees have a lower result in named subtopic (Appendix A-1). This subtopic contains lots of symbolic representation in an electrical diagram that can create wrong interpretation and misconception toward the contents. Based on this informal finding, instructional materials need to be developed that will help to reduce the misconception (Yang, Greenbowe, & Andre, 2009).

A new instructional approach must be developed so that learners can master conceptual and procedural knowledge and understanding related to circuit diagrams to transfer their knowledge in the new scenario of an authentic job task (Moreno et al. (2009). In line with technology advancement of the 21st century, TVET has embraced information and communication technology (ICT) into its teaching and learning processes (UNESCO IITE, 2012; UNESCO Institute for Information Technologies in Education (IITE), 2005). With ICT integration, training materials that provide multiple sensory inputs are making training more efficient and effective when our senses respond favourably to these training materials (Felder & Silverman, 1988). For example, vocational trainees have shown to develop a very good understanding of shoe design when virtual training is used in the shoe design course (Sahin, 2010). Another study shows that continuous animation format has the highest efficiency in teaching electrical circuit diagram (Ng, Kalyuga, & Sweller, 2013). Karahoca et al. (2010) study also concludes that bring ICT into teaching and learning session can overcome the shortage of teaching staff especially in vocational education and training. Additionally, teaching electrical circuit using a variety of example offer problem solving skills among engineering students (Moreno et al., 2009). Melo & Miranda (2014) have been using four components instructional design (4C/ID) to design an electrical circuit instruction

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